Mechanical and Electrical Design of an Octopod

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Abstract

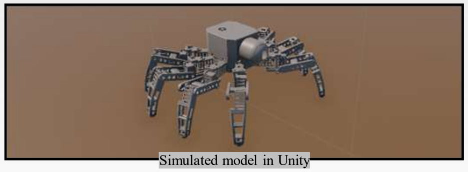
The goal is to design and build a sturdy and mobile chassis for an eight-legged robot, or octopod, with electrical and mechanical components capable of supporting the robot's weight and powering the various components. To verify system requirements such as scale and servo strength, a simulation was developed in Unity. The legs of the rover each have three degrees of freedom to allow for movement in all three axes. A gimbal design is used for orienting a distance sensor to detect obstacles in a wide field of view without the need for multiple sensors. The power system makes use of buck converters to regulate logic and motor voltage. All mechanical parts were designed in Fusion 360 and 3D printed in polylactic acid (PLA) which has plenty of strength to support the robot in motion.

Introduction

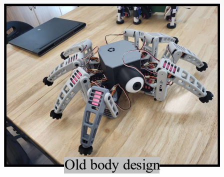
The octopod in question was developed for participation in the Colorado Space Grant Consortium Robotics Challenge by team Arachnid. For the challenge, the robot must operate autonomously to navigate sandy and rocky terrain, not dissimilar to that of Mars. The robot was limited to a maximum weight of 5kg and built with a budget of $500. Development of the robot lasts for roughly seven months after which it is tested on five courses at the Great Sand Dunes national park near Alamosa, Colorada. The goal was to improve upon a previous hexapod design by improving navigation speed and implementing more degrees of freedom for smoother and more adaptable movement.

Testing

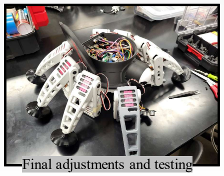
The rover was first tested using a simulation in the Unity game engine. This helped in determining the required servo strengths and ensuring that the mechanical components did not interfere with one another. Subsystems were later tested in isolation before being combined to test the assembled robot as a whole. The robot was tested both indoors and outdoors.



Simulated model in Unity



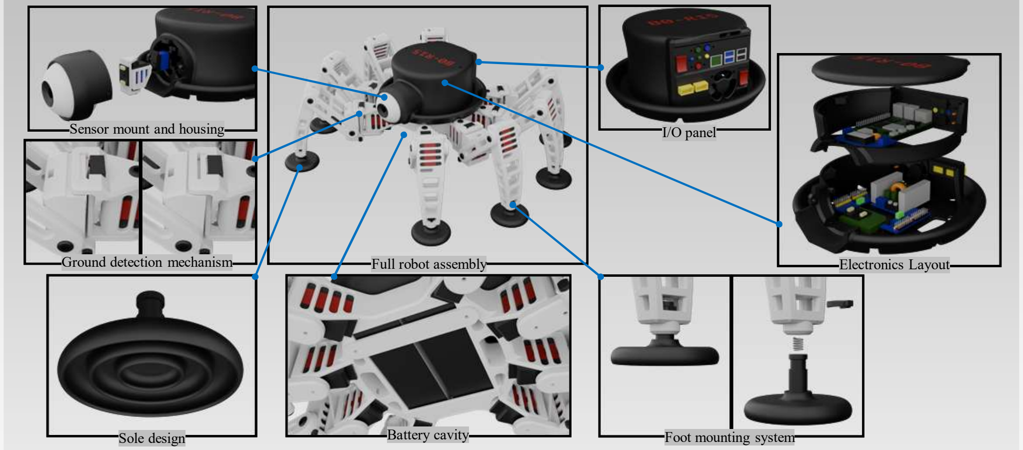
Old body design



Final adjustments and testing

Mechanical

All mechanical parts were designed in Fusion 360 and printed in PLA (Polylactic Acid) except the feet which were printed in TPU (Thermoplastic Polyurethane) for its rubber-like properties. A housing was designed for the electronics in the shape of a top hat and sits atop the center of the octopod. The housing was designed with an I/O panel at the back to allow for connectivity, control, power control, and battery swapping without the need to open the chassis. The batteries are mounted in an external cavity on the underside of the chassis allowing for easy access. For the obstacle detection distance sensor, a gimbal system was designed with an eyeball-like enclosure allowing for wide view, sunlight protection, debris protection, and an aesthetically interesting design. The leg was designed to allow for three degrees of freedom, it consists of one horizontal joint and two vertical ones. The ground detection was placed at the hip, using a hinge mechanism and limit switch. Usually, the ground detection is at the foot or in the tibia, this design has ground detection at the hip for greater reliability in abnormal positioning. The foot mounting mechanism allows for interchangeable feet with optional suspension. Using a clip-and-pin method for securing the foot allows different designs to be easily exchanged. The foot design is wide so as not to sink into sand and has concentric ridges on the sole for grip.



Sensor mount and housing

Full robot assembly

I/O panel

Electronics Layout

Ground detection mechanism

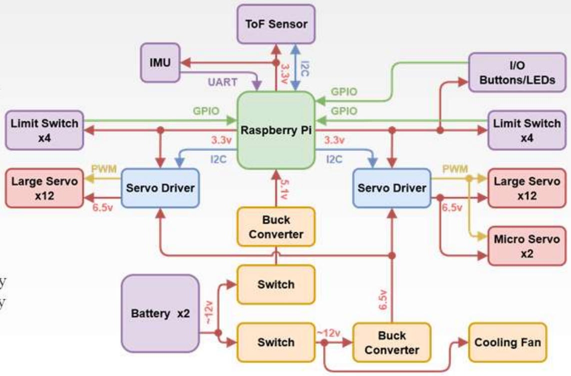
Sole design

Battery cavity

Foot mounting system

Electrical

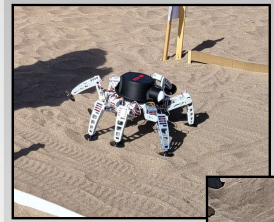
All electrical components draw power from a pair of 5200mah 3S LiPo batteries wired in parallel for a total of 10400mah of battery capacity. There are two switches, one that controls the power to servos and the cooling fan, and another that controls power to the Raspberry Pi. The servo power is regulated down to 6.5 volts using a buck converter that can handle 20 amps of current. The power to the Raspberry Pi is regulated down to 5.1 volts with another, smaller buck converter. All sensors and logic devices are powered at 3.3 volts from the Raspberry Pi. The Raspberry pi interacts with the distance sensor and the servo drivers using I2C (Inter-Integrated Circuit). The IMU is monitored using UART (Universal Asynchronous Receiver Transmitter). The ground detection limit switches, input buttons, and output LEDs are connected to and controlled by GPIO (General Purpose Input Output) pins on the Raspberry Pi. The servo drivers control the servos using PWM (Pulse Width Modulation) signals. The devices used are the Raspberry Pi 5, the VL53L4CX time of flight sensor, the BNO085 9-DoF IMU, and the PCA9685 16-channel servo drivers. The servos used were eight 20kg servos, eight 25kg servos, eight 35kg servos, and two micro servos.



Electrical block diagram

Results

The rover performed well at the sand dunes, clearing two out of five courses and coming close on two more. It won two awards for attention to detail and best all around rover. The mechanical design held up to the robot's movements and there were no mechanical failures even while navigating large obstacles and inclines. The electrical components performed great as well, there were no servo motor failures, and the power delivery system held up for the entire length of the challenge. However, there was a major issue with the electrical system, and that has to do with the distance sensor used on the robot which did not perform reliably in sunlight. This resulted in the robot only being able to operate in "blind mode", where the robot just walks straight and ignores obstacles.



Rover on multiple courses at the Great Sand Dunes national park

Conclusion

Overall, the robot performed great aside from the obstacle detection. Some improvements to be made would include a more reliable distance sensor, LIDAR, or a multi-camera setup, for obstacle detection. The grip of the foot design could also be improved, while it works great for rough terrain and rocks, it tends to slip on smooth surfaces, especially when inclined.